AN APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY WITHIN THE STANDARD BASE SUPPLY SYSTEM

THESIS

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The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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THESIS

Presented to the Faculty of the

School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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Captain, USAF

September 1991

Acknowledgments

The completed research effort embodied in the pages to follow would not have been possible without the unselfish assistance of several individuals "behind the scenes". I would like to express my sincere appreciation to each of these individuals, without whom this project could never have come to fruition.

In particular, my thanks go to my thesis advisor, Captain John Sullivan, who provided me with just the right balance of academic freedom and timely guidance; his help was invaluable to the completion of the research. My thesis reader, Lt Col James Holt, also has earned my sincere gratitude for his assistance in this thesis, and for "turning me on" to the world of artificial intelligence and expert systems.

I would like to thank my good friend, Dave Jones, for his advice, friendship, competitiveness, and level head while we each struggled to complete our theses. When I think of the time Dave and I had with AFIT, the words of an American soldier following World War II come to mind: "We sure liberated the hell out of this place."

Finally, I would like to thank my wife, Charlotte, and my wonderful children, Amanda, Christopher, and Zachary, for keeping my "feet on the ground" during these past 15 months; without my family, my education means nothing.

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Abstract

This thesis investigated the feasibility of applying artificial intelligence technology within the Standard Base Supply System (SBSS). With seemingly endless reductions in manpower authorizations within the SBSS and the potential for a continued loss of expert knowledge, the use of knowledge-based systems (KBSs) was examined to determine if these systems could alleviate this loss of manpower.

Literature related to the fields of artificial intelligence, expert systems, and KBSs was traced, yielding a methodology for identifying candidate problems, and for the development, verification, and validation of prototype KBSs. This methodology was then employed within the research, culminating in the creation, verification, and validation of a prototype KBS.

The research resulted in several conclusions: 1) Supply-related tasks do lend themselves to KBS development; 2) A small-scale Supply KBS is feasible with limited resources; and 3) A small-scale Supply KBS can be validated.

Several follow-on studies were recommended, with the thrust being that additional KBSs should be developed, tested, and placed into operational use within the SBSS.

AN APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY WITHIN THE STANDARD BASE SUPPLY SYSTEM

I. Introduction

General Issue

The development of artificial intelligence and, more recently, expert systems technology has led to numerous lucrative applications within the scientific and business communities. It is estimated that there are over 2,000 operational expert systems in use currently within the United States, approximately 80 percent of which support PC applications (Norville, 1990:24).

By providing the capacity to capture the key decision heuristics of experts for subsequent use by a wide range of users, expert systems have provided a valuable tool for the management and dissemination of often-scarce human expert knowledge. Expert systems have been used in a wide array of applications; Waterman summarized the "generic categories of expert systems applications" as presented in Table 1.

The tremendous potential of expert systems technology has been exploited in numerous ways. Waterman provides a good overview of several highly successful expert system applications, as seen in Table 2.

Table 1

EXPERT SYSTEM GENERIC CATEGORIES

Category	Problem Addressed
Interpretation	Inferring situation descriptions from sensor data
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observations
Design	Configuring objects under constraints
Planning	Designing actions
Monitoring	Comparing observations to expected outcomes
Debugging	Prescribing remedies for malfunctions
Repair	Executing plans to administer prescribed remedies
Instruction	Diagnosing, debugging, and repairing student behavior
Control	Governing overall system behavior

(Waterman, 1985:33)

One fairly recent off-shoot of expert systems technology involves the use of systems which synthesize the judgemental or intuitive knowledge of human experts with established written directives in an attempt to provide what has been referred to as a knowledge-based system (KBS). (Norville, 1990:22).

While the distinction between traditional expert systems and KBSs could be seen as slight, it is nevertheless

Table 2

EXPERT SYSTEM SUCCESSES

Type	Name	Application
Research:	SYNCHEM2	Synthesizes complex organic molecules without help from a chemist
	DENDRAL	Identifies molecular structure from mass spectral data
	MACSYMA	Solves algebraic simplification and integration problems
Business:	ACE	Provides trouble-shooting reports and analyses for telephone cable maintenance
	DELTA	Helps diagnose and repair diesel electric locomotives
	SPE	Diagnoses inflammatory conditions by interpreting scanning densitometer data
	XCON	Configures VAX 11/780 computer systems

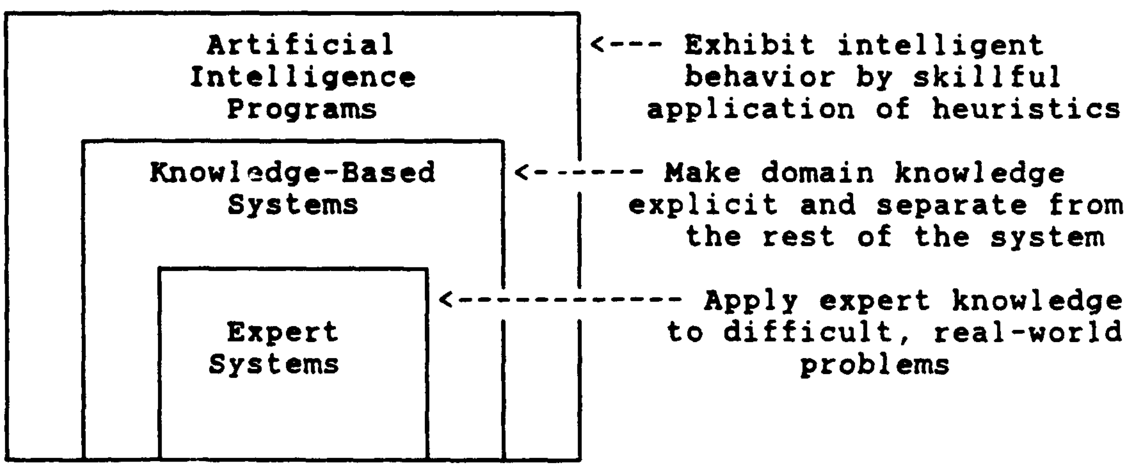
(Waterman, 1985:213)

important to understand the difference.

The term expert system, in the context of this thesis, refers to a computer system which has been developed through a complex interaction between a knowledge engineer and a human expert. In this process, the knowledge engineer attempts to extract as much of the knowledge and expertise of the human expert and to code this information into the

knowledge base of an expert system, for subsequent use by non-experts.

In contrast, the term knowledge-based system represents a subset of expert system technology, with the key distinction being that in a KBS, the knowledge engineer extracts information from a <u>variety</u> of sources (e.g., paper manuals and regulations, one or more human experts, etc.) to shed light on a particular subject. Thus (as illustrated by Figure 1), "virtually all expert systems are knowledge-based systems, while the converse is not necessarily true" (Waterman, 1985:18).



(Waterman, 1985:18)

Figure 1. Overall AI Structure

KBSs lend themselves well to the rapid retrieval and display of context-specific information, such as that found in large paper manuals or regulations. Norville found that "Expert systems that help staff wade through complex

regulations [as KBSs do] are a natural for agencies [which possess a great deal of paper guidance]" (Norville, 1990:22).

In addition, KBSs which manage to synthesize the ability to quickly access context-specific regulatory guidance with the ability to access imbedded human judgemental knowledge can provide a particularly potent combination for problem solving in organizations characterized by: 1) a relative shortage of human experts; and 2) a fairly rigid, regulation or manual-driven set of procedures.

Justification for the Research

Despite the highly visible and demonstratively profitable use of expert system technology within the science and business communities over the past 10 years, the application of this technology has seen only limited use within the U.S. military logistics structure. With the potential for more-restrictive budgets in the future and the ever-present drive within the U.S. military structure to "do more with less," there exists a need to incorporate expert system technology into logistics areas which appear likely to benefit from this technology.

Recognizing this need, Col Douglas Blazer, currently serving on the Air Staff at the Pentagon (Office Symbol HQ USAF/LGX), has proposed via an Air Force Institute of Technology Form 53 ("External Proposal - Thesis Research Topic" - see Appendix A) that research be conducted regarding the general feasibility of expert system applications within

the major logistics functions in the United States Air Force, encompassing the Transportation, Supply, Maintenance, Engineering, Logistics Plans (LOGPLANS), and Contracting areas.

In his proposal, Col Blazer recommends that research be conducted to actually "build a prototype expert system for a particular logistics process application" within one of the major logistics functions.

Within the United States Air Force, the Standard Base Supply System (SBSS) represents a logistics function which exhibits characteristics closely aligned with those described above (in the discussion on what type of organizations could benefit most from KBS implementation). The SBSS is in itself a complex system encompassing several different functional organizations; this system is represented at the base or wing level by the Supply Squadron.

Traditionally, base-level Supply Squadrons have possessed a shortage of human experts. This shortage has been exacerbated in recent years due to the general drawdown in forces. According to CMSgt Richard E. Grist, who is responsible for managing the enlisted force within the 645XX (Supply) career field at the Air Force Military Personnel Center (AFMPC), the problem is twofold: 1) Authorizations for enlisted Supply Squadron members have been cut steeply in recent years, yielding an overall smaller Supply force; and 2) The absolute number of Supply enlisted personnel has been

in a state of nearly constant reduction over the past two years.

The net effect of these two simultaneous actions has been that Supply manning levels, as a percentage of authorizations, have remained relatively stable (as the authorizations have dropped at roughly the same rate as personnel reductions have occurred), while the actual number of supply personnel responsible for essentially the same tasks has rapidly dwindled. Thus, while on paper the Supply enlisted career field would appear to be relatively healthy, it has suffered relatively deep cuts in recent years (Grist, 1991).

Of particular note regarding the drawdown in the Supply enlisted force is the fact that a majority of the cuts have come in the form of reduced accessions. For example, in the 645X0 Supply career field, accessions for 1989 were approximately 1,600; accessions for this career field in 1992 are projected at only 500 (Grist, 1991).

As a result of this reduction in accessions, current manning levels for 3-level (64530) Supply personnel stand at only 56 percent. At the present time, sufficient numbers of 64550 personnel exist to make up for the shortage of the 3-level Supply personnel. However, by cutting the number of accessions so steeply, it is felt that over time the problems associated with loss of expert knowledge will grow, as experienced Supply personnel separate or retire, and an

inadequate number of less-experienced personnel are available to fill their positions (Grist, 1991).

Thus, the potential exists for an expertise "black hole", in which experienced Supply technicians depart the Air Force, taking their expertise with them without adequately passing these skills on to the relatively smaller number of younger Supply technicians.

Despite this potential for future problems, very few inroads have been made in the Supply discipline in the development and implementation of KBS technology, which represents one possible way to capture the knowledge and experience of departing Supply technicians.

Problem Statement

The current shortage of highly skilled base-level supply technicians, coupled with ongoing and impending DOD manpower cuts, has the potential to reduce the effectiveness of base-level supply organizations. According to CMSgt John Babbitt (HQ Air Force, LGSS), Senior Supply personnel at all levels within the Air Force must seek solutions to the problems associated with the ongoing loss of experienced supply technicians (Babbitt, 1991).

One solution to this problem may come with the development and implementation of KBSs within the supply discipline. Therefore, this thesis will examine the applicability and feasibility of implementing expert system

technology (in the form of a KBS) to stem the loss of expert knowledge within the base-level supply organization.

Research Questions

To address the research problem, the following research questions were posed:

1. Do supply-related tasks lend themselves to KBS development?

2. If supply-related tasks lend themselves to KBSs, how can a prototype KBS be developed within the Standard Base Supply System?

3. How can this prototype KBS be validated?

Research Objectives

This research was conducted with two primary objectives in mind.

First, this research attempted to demonstrate the feasibility of developing a prototype KBS for a specific logistics process application.

Second, from a more pragmatic standpoint, this research attempted to provide a concrete solution to a current supply-related problem occurring within the U.S. Air Force.

Scope of the Research

Since the potential applications of KBS technology within an organization as complex as a base-level supply account are virtually limitless, it was first necessary to determine the scope of this research or, more specifically,

the number of KBSs to be developed, validated and implemented.

Given the limited time available for this research and the inherent complexity of identifying, designing, validating and implementing an KBS, this research focused its efforts on a single supply-related problem.

To further limit the scope of this research to a manageable level, a single expert was selected to provide the judgemental knowledge to be embedded into the KBS. A review of past literature regarding the optimal number of experts to use in developing an expert system (or KBS) indicated that in many cases a single expert was actually preferred to multiple experts. In this case, an individual within Wright-Patterson Air Force Base's Supply Squadron was used, chosen primarily for the easy accessibility afforded by Wright-Patterson AFB. However, additional equipment experts at the base, MAJCOM, and HQ USAF level were used in the program-validation phase of this thesis.

Limitations of the Research

The restricted scope of this research, as outlined above, necessarily imposed several limitations on this study. The use of a single expert in the creation of this expert system (while fairly common in practice), as well as the restriction to a single base-level Supply Squadron, could limit the applicability of the finished product within other base-level Supply Squadrons in the Air Force. The reason for

this potential limitation is that Major Commands (MAJCOMs) are allowed a certain amount of latitude in determining specific methods of task performance. Oftentimes, specific methods for performing supply tasks are MAJCOM or even base-specific. Thus, the KBS which was developed in an Air Force Logistics Command base-level Supply Squadron may or may not be directly useable by another Supply Squadron within another MAJCOM.

However, it is believed that the relatively minor deviations allowed to individual MAJCOMs may be dealt with effectively within a KBS by either: 1) making the application generic for all Air Force supply accounts by not addressing issues which are MAJCOM-specific; or 2) by providing a mechanism for individual MAJCOMs (or bases) to tailor the system to their own unique needs. Further, this potential limitation was partially eliminated through the use of a multi-level validation process, in which equipment experts at the base, MAJCOM, and HQ USAF level were used to validate the KBS.

Summary

Chapter I provided a basic foundation of information for the research accomplished in this study.

It began with a discussion of the burgeoning technology of artificial intelligence and expert systems, which have provided valuable methods for the capture and dissemination of often-scarce expert knowledge within an organization.

Next, it discussed the technology of KBSs in relation to the U.S. Military logistics structure, defining the current need to integrate this new technology into the various logistics functions in order to increase efficiency and stem the imminent loss of expert knowledge within the logistics community caused by general reductions in manning levels.

Narrowing its focus, Chapter I next discussed one specific U.S. Military logistics function which possesses characteristics of an organization which could potentially benefit from the introduction of KBS technology: the base-level Supply Squadron, represented by the Standard Base Supply System (SBSS).

The SBSS represents a system which encompasses several supply organizations, many of which possess functional areas requiring the availability of an expert. With expert shortages currently existing in several supply functions, and the strong possibility of future losses of expert knowledge caused by reductions in manning levels, the SBSS faces the challenge of maintaining the necessary expertise to complete all functional requirements (Babbitt, 1991).

One possible answer to this problem comes in the development and use of a prototype KBS to be used to solve a current supply-related problem.

After this brief introduction into the world of KBS technology and discussion of the specific problem within the SBSS, Chapter I continued by establishing three research

questions to be answered in solving this problem. Further, it described the research objectives, related the overall scope of the thesis, and gave several limitations anticipated in conducting this research.

Chapter II will provide a review of current literature regarding artificial intelligence and expert systems, will discuss pertinent issues regarding KBS development, will examine selected methodologies found in the literature for creating and testing expert systems (and KBSs), and will provide a general overview of the structure of the SBSS.

II. Review of the Literature

Overview

To conceptualize the specific activities involved in KBS development, it will first be necessary to develop a foundation of knowledge in the broader subject of artificial intelligence (AI). Thus, Chapter II will begin with a discussion of AI, tracing the roots of this discipline from inception up to the point in time at which the subfield of expert systems was created.

Next, a knowledge of the more specific area of expert systems is presented, including a brief outline of the historical developments in the field of expert systems.

Next, the focus of the chapter turns to KBSs, specifically discussing three individual topics:

1) The typical expert system/KBS structure;
2) Selecting candidates for KBS implementation; and
3) Management of KBSs.

Finally, a brief overview of the structure of the SBSS is presented, in order to provide the reader with a basic understanding of the system being discussed.

Artificial Intelligence

Artificial intelligence; what is meant by the term? Definitions of AI are many and varied, as noted by Morris Firebaugh in his book Artificial Intelligence: A Knowledge-Based Approach. Firebaugh presents a good compilation of

popular definitions of AI, each taken from a different source having a slightly different point of view. For example, Firebaugh presents the machine-oriented perspective of Patrick Henry Winston, who defined AI as: "the study of ideas that enable computers to be intelligent" (Firebaugh 1988:12).

Next, Firebaugh quotes the ostensibly mind-oriented viewpoint of Charniak and McDermott (1985), who defined AI as: "the study of mental faculties through the use of computational models" (Firebaugh 1988:12).

Peter Bock's more comprehensive definition of AI (as reported by Firebaugh) was: "the ability of a human-made machine (an automation) to emulate or simulate human methods for the deductive and inductive acquisition and application of knowledge and reason" (Firebaugh 1988:12).

Finally, Firebaugh quotes Professor Marvin Minsky of MIT, who gave the concise yet comprehensive definition of AI, as: "the science of making machines do things that would require intelligence if done by men" (Firebaugh 1988:12).

A Brief Historical Perspective of AI

The field of artificial intelligence, which continues to receive a great deal of attention and research in today's academic and business environment, had its roots in the mid 1950s (Allen, 1986:4). Allen, paraphrasing Feigenbaum and Feldman's classic AI book, Computers and Thought, states that:

> AI research began in the mid 1950's, spurred in part by scientists' preoccupation with the now famous Turing Imitation Game. The Turing Game was a test to determine whether or not a machine could fool a human in an interrogation game. The machine was considered to possess intelligence if the person performing the interrogation was unable to distinguish the machine's responses from another human's. (Allen, 1986:4)

Additionally, according to Schoen and Sykes (1987),

> the field of artificial intelligence, or at least the name, was created at a summer conference in 1956 at Dartmouth College that was organized by Marvin Minsky, John McCarthy and Claude Shannon. (Schoen and Sykes, 1987:2)

Optimism for the use of AI technology and applications ran high throughout the period of 1950 through 1970, as observed in a Dartmouth College study written in 1956 (as reported by Firebaugh, 1988), which stated:

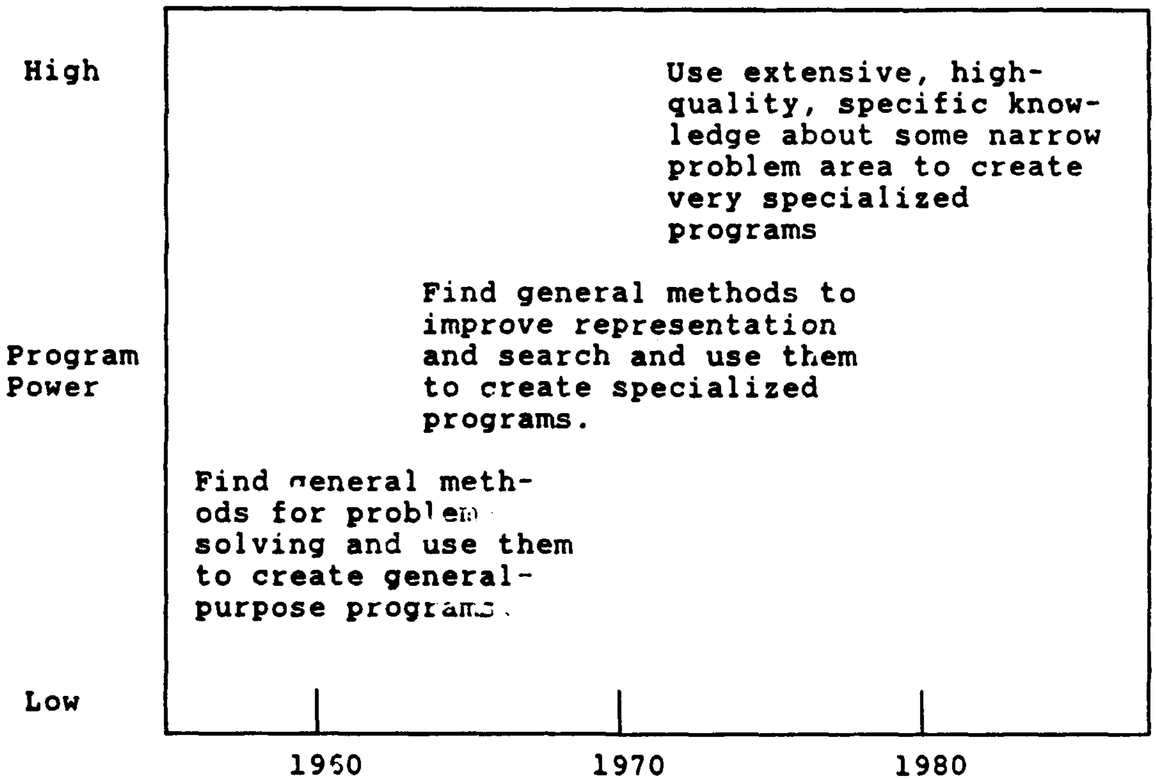
> The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. (Firebaugh, 1988:18)

Unfortunately, this optimism would not come to fruition during the period 1950 through 1970, as evidenced by J. Lighthill's statement in a study funded by the British Government (again, as reported by Firebaugh, 1988): "... in no part of the field have the discoveries made so far produced the major impact that was promised" (Firebaugh, 1988:18).

However, during this period, several advances were made which kept the study of AI alive. For example, the advent of

list processing languages such as FORTRAN, COMIT, and LISP created the technological foundation upon which subsequent AI research was grounded (Allen, 1986:5).

To summarize the shifting emphasis within the AI community over the history of this discipline, Waterman presents the following figure (Figure 2, below).



(Waterman, 1985:4)

Figure 2. Historical AI Research Focus

The advancements in the field of AI from the 1970s to present include the development of expert systems and, subsequently, KBSs. Thus, a brief historical perspective of expert systems is presented next.

Expert Systems

Like AI, the term "expert system" has been given a number of different definitions over the past 20 years. Lindsay (1988) defines expert systems as:

> software programs that solve problems by mimicking the ways in which human beings solve problems. In the strict terms used by many researchers, expert systems apply expertise; they behave just as human experts do whose advanced training or experience equips them to do the work of several, and to do it brilliantly every time. (Lindsay, 1988:12)

A second definition of expert systems is given by Baswas *et al.* (1988), who state that:

> Expert or knowledge based [sic] systems are simply application programs that emulate human experts in specialized domains. Their ability to solve complex problems is based on the creation of a comprehensive knowledge base that includes relevant facts and heuristics developed by experts in a given domain. (Baswas *et al.*, 1988:235)

Of particular note in the Baswas *et al.* definition is the term heuristics, which is mentioned frequently in discussions on expert systems. A heuristic is any "rule of thumb, strategy, trick, simplification or any other kind of device which drastically limits search for solutions in large problem spaces" (Feigenbaum and Feldman, 1963:6).

A Brief Historical Perspective of Expert Systems

The development of list processing languages such as FORTRAN, COMIT, and LISP in the 1960s were, according to Allen, "crucial to the feasibility of expert systems"

(Allen, 1986:5). With this computer language capability came the power to manipulate symbols and to come to certain conclusions based upon these symbols (Allen, 1986:5).

"Work by Joshua Lederberg in 1964 led to the development of the DENDRAL program at Stanford University under the direction of Edward Feigenbaum" (Schoen and Sykes, 1987:2). In discussing the relative importance of the development of DENDRAL, Allen paraphrases Feigenbaum and McCorduck, stating: "DENDRAL was a key turning point towards other knowledge-based AI programs" (Allen, 1986:5). Mishkoff states that Feigenbaum, by overseeing the development of DENDRAL, "pioneered the rule-based approach that is currently popular in the development of expert systems" (Mishkoff, 1985:38).

Speaking of the expansion of expert systems research, Allen (1986) states "Expert systems really began to flourish in the mid 1970's, as AI research centers were formed at increasing numbers of educational institutions" (Allen, 1986:6). Allen goes on to note that:

> The decade of the 1980s saw the first introduction of expert systems for daily use in business and industry. The first system XCON, short for expert configurer, was introduced at Digital Equipment Corporation in 1980. (Allen, 1986:6)

Summarizing the trend towards the continued use of expert systems, Allen notes that "The trend of the 1980s towards increased use of expert systems to address the large volume of nontechnical problems involving decisions or assessments is projected to accelerate" (Allen, 1986:5).

Structure of an Expert System

Structurally, an expert system is composed of three main parts: a knowledge base, an inference engine, and an explanation subsystem.

In discussing the knowledge base, Donald Waterman notes:

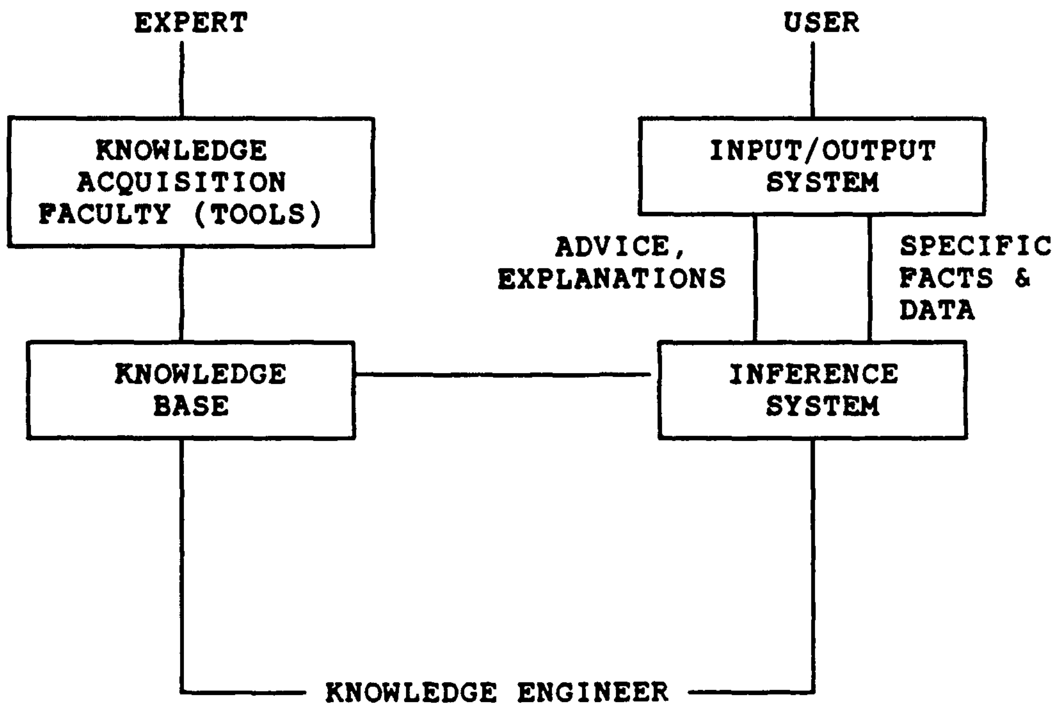
> The knowledge in an expert system is organized in a way that separates the knowledge about the problem domain from the system's other knowledge, such as general knowledge about how to solve problems or knowledge about how to interact with the user. This collection of domain knowledge is called the knowledge base... (Waterman, 1985:18)

The inference engine, a second major component of an expert system, is quite simply the area within the system which is responsible for searching through the knowledge base in an organized way (following set knowledge rules) to come to a solution (Van Horn, 1986:165).

Finally, the explanation subsystem within an expert system serves to provide the user with the ability to query the system to determine its line of reasoning in coming to its conclusions (Keim and Jacobs, 1986:9).

Feigenbaum and McCorduck describe the structure of an expert system as shown in Figure 3.

Essentially, Figure 3 provides, in addition to the fundamental structure of an expert system, an overview of how the flow of knowledge is transferred from the source (human expert) to the ultimate user. The knowledge engineer, or system designer, assists the process by extracting the knowledge and heuristic rules from the human expert, creating



(Feigenbaum and McCorduck, 1983:76)

Figure 3. Expert System Components

a knowledge base and inference system from this information, and overseeing the prototype development and validation.

Allen, confirming Feigenbaum and McCorduck's expert system model, notes that the knowledge base contains both basic facts and heuristic knowledge, while the inference engine "provides overall control of the system" (Allen, 1986:18).

O'Leary (1988) discusses the fundamental structure of an expert system as follows:

> Structurally, an expert system usually consists of four major components: a data base, a knowledge base, an inference engine, and a user interface. The data base contains the data used by the expert system... The

> knowledge base contains the knowledge that the expert system uses to process the data... The inference engine is the reasoning approach used in the program to process the knowledge base... The user interface defines the manner in which the system elicits information and explains its conclusions. (O'Leary, 1988:73)

Candidates for Expert System Implementation

According to Bielawski and Lewand (1988), "it is quite clear that certain kinds of tasks performed by experts lend themselves to PC-based expert systems technology better than others" (Bielawski and Lewand, 1988:11). So how does one decide on a specific application for development of an expert system?

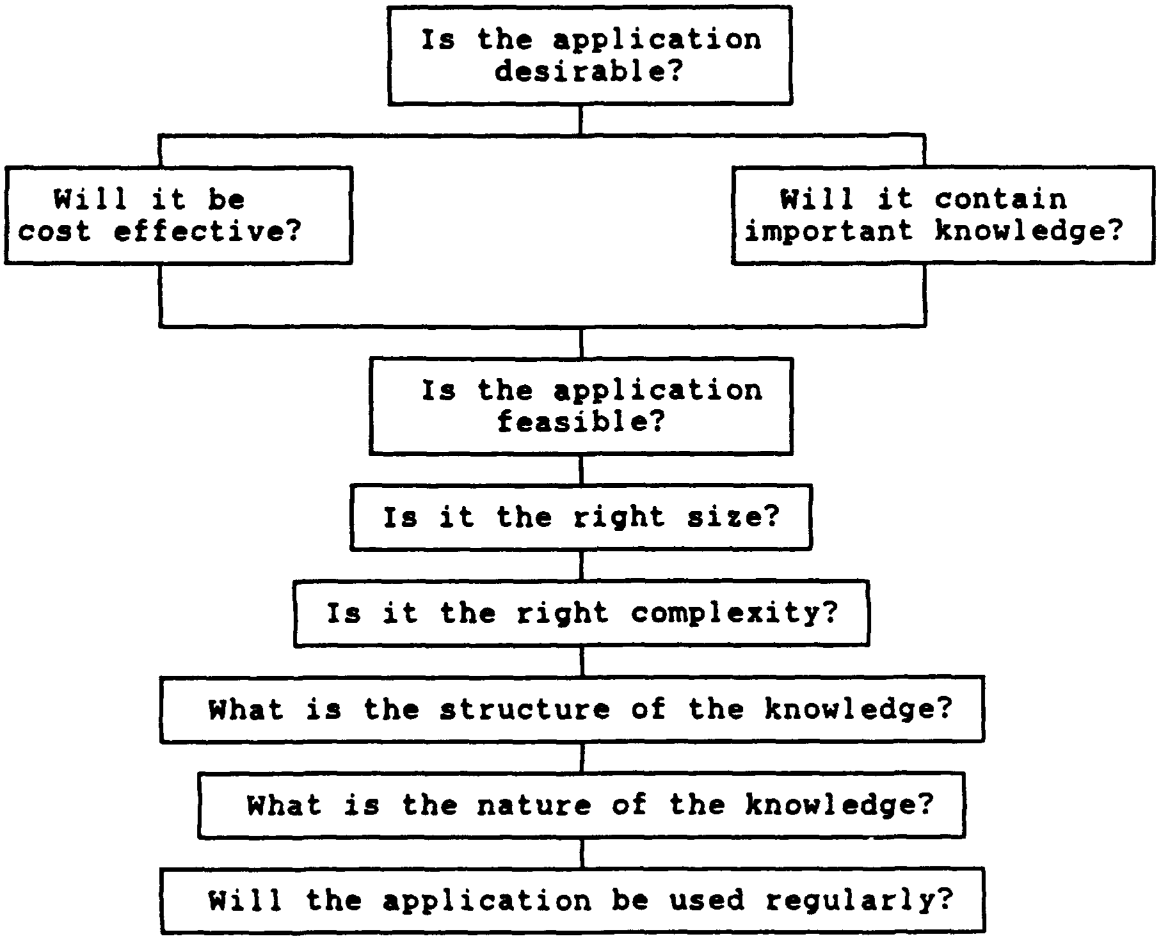
Bryant, writing on this very subject, proposes that a series of questions must be asked before initiating an expert system/KBS project. These questions are presented in Figure 4.

Further, according to Bryant:

> An expert system, like any software, is desirable if it does one of two things. Either an expert system should be cost effective by increasing revenue or reducing costs or, alternatively, it should contribute to the efficiency of an organization by providing expertise that otherwise would not be available. (Bryant, 1988:32)

Grimaldi and Marcelli propose a slightly different method for determining the feasibility of an expert system. They assert that determining feasibility should be the fifth phase of a five-part plan. These parts are:

1) Searching for the expert.
2) Characterizing the problem.
3) Describing the knowledge.



(Bryant, 1988:33)

Figure 4. Criteria for Evaluating Potential Expert System Applications

4) Using the knowledge.
5) Evaluating the feasibility. (Grimaldi and Marcelli, 1989:27)

Van Horn sets forth two fundamental principles to keep in mind when deciding to create an expert system. The first of these principles is, "An expert system requires some real expertise in the field. Either you must be the expert, or be able to build the expertise through experience" (Van Horn,

1986:58). Van Horn's second key principle in developing expert systems is:

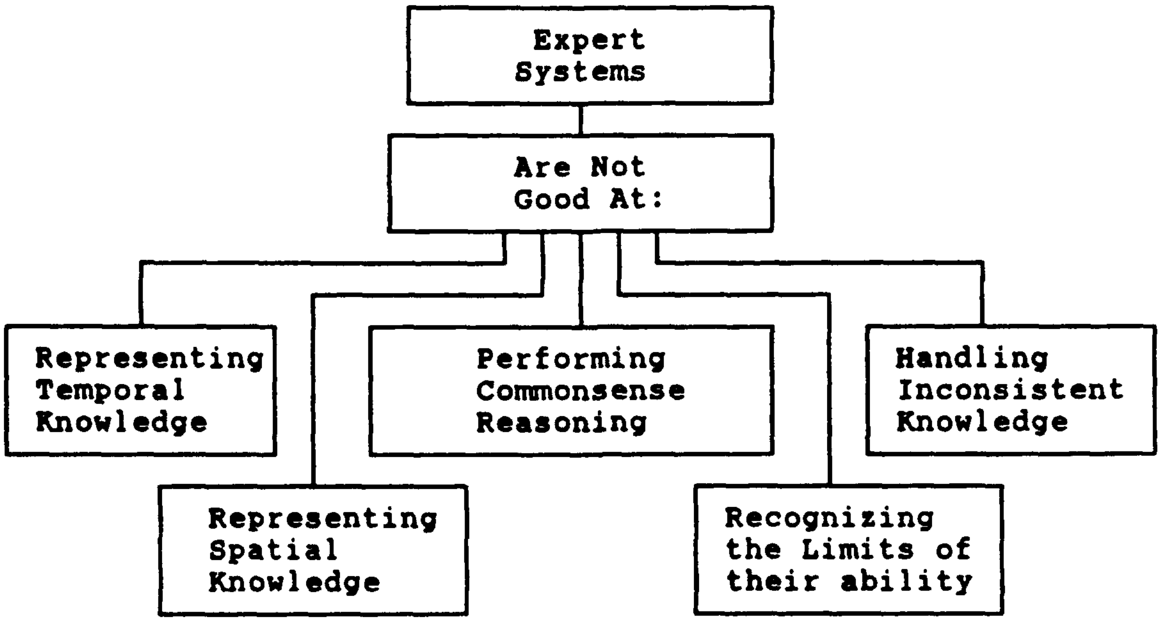
> Expert systems rarely perform better than the experts. The problems on which expert systems outperform human experts are not tasks about which they know more than the humans, but about which they forget less. (Van Horn, 1986:58)

Schoen and Sykes highlight the need to include criteria in the planning process for an expert system with which to determine whether or not the expert system is successful (Schoen and Sykes, 1987:170). They state that:

> Examples of criteria that might be used to define success are that a system:
>
> 1. Solves representative problems satisfactorily.
>
> 2. Increases the effectiveness of the user in a demonstrable way.
>
> 3. Provides recognizable product enhancement or features.
>
> 4. Responds to a market opportunity or pressure in a specific manner.
>
> 5. Satisfies the check-signer. (Schoen and Sykes, 1987:170)

Waterman discusses the limitations inherent in any expert system project; Waterman's discussion is portrayed in Figure 5.

"Just because it's possible to develop an expert system for a particular task doesn't mean that it's desirable to do so" (Waterman, 1985:130). In order to justify the time and money involved with undertaking an expert system/KBS project, Waterman developed Figure 6.



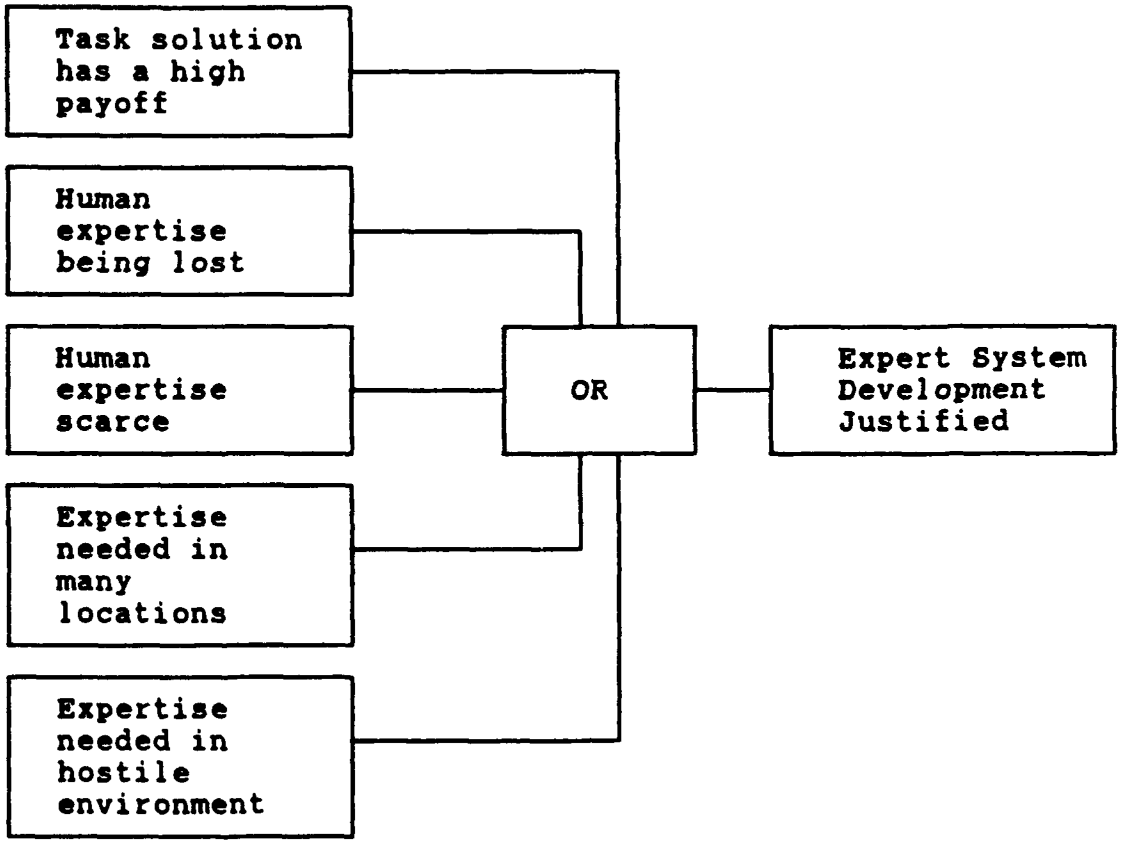
(Waterman,1985:181)

Figure 5. Expert System Limitations

Finally, Waterman summarizes the necessary requirements for any expert system/KBS development project (see Figure 7).

Expert System/KBS Project Management

The overall management of expert systems and KBSs is generally considered to require "more effort and insight than comparable, traditional information systems projects" (Eliot, 1989:24). One reason for this, according to Eliot (1989), results from the inevitable lag which occurs between the time that new technology -- in this case KBS technology -- becomes available and the time that managers of the new technology become proficient in its development and overall maintenance.



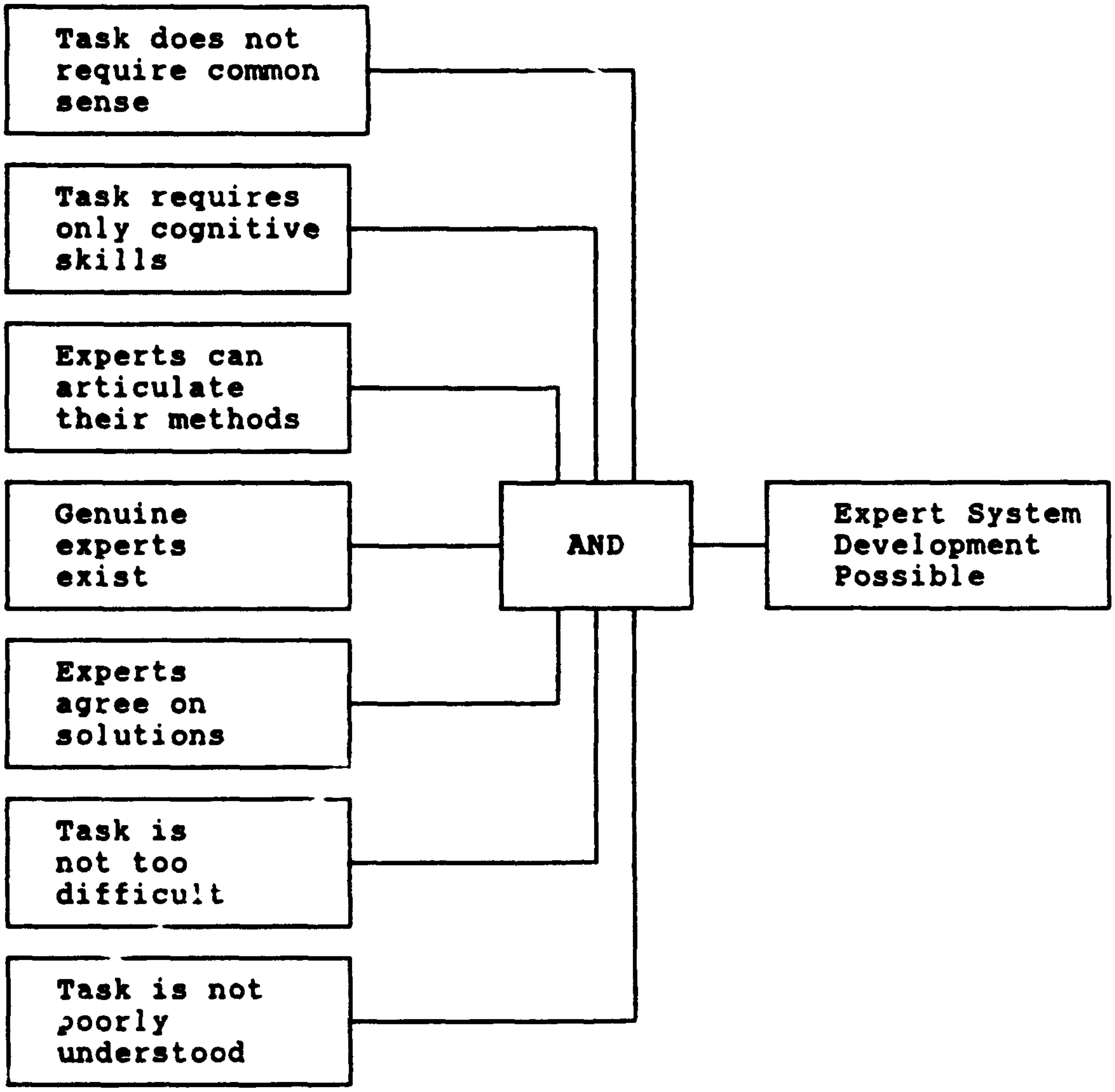
(Waterman, 1985:130)

Figure 6. When is an Expert System Justified?

Norville contends that:

> Maintenance can be a problem in these [KBS] systems. You can't go in and change things. You run the risk of destroying the logic in closed domains. Adding to or correcting it [the KBS] can be difficult. Maintenance is an issue organizations will have to address, especially as knowledge-based systems become more complex. (Norville, 1990:24)

Martino recommends that the knowledge engineer should plan for a built-in maintenance capability in designing KBSs, including the capability of "adding new rules as needed" and "purging obsolete rules" (Martino, 1991:3).



(Waterman, 1985:129)

Figure 7. When is an Expert System Feasible?

In addressing the overall management of expert system projects, Eliot used the case-study approach to describe the successes and failures among different methods of overseeing KBS projects, resulting in several useful points regarding this issue. For example, Eliot found that "Expert systems should not be used just because the competition is using

them" (Eliot, 1989:25). He also stressed the importance for organizations to keep current in recent developments in expert system technology, in order to more realistically judge the worth of embarking upon a new KBS project.

The issue of KBS management becomes even more critical within the context of the Air Force environment, where regulations and manuals are constantly updated and where individual bases and Major Commands are allowed a degree of latitude in establishing procedures.

How then could an KBS remain updated and useful within the Air Force, and more specifically, the Air Force's base-level supply account? In order to answer this question, an individual possessing experience in overseeing the development and management of a micro-computer based project at the Major Command level was contacted. Mr. James Turner, currently serving on the staff at HQ Air Training Command and acting as the manager for a command-wide clothing-issue program, described the development and management of a micro-computer based program as follows:

While many micro-computer based programs are generated by the Air Force Logistics Management Center at Gunter Air Force Base, programs may be developed at any organizational level by individuals with programming experience who perceive an unmet computer requirement. Once a program is developed and initially tested for validity and accuracy, the developer may attempt to "sell" the program to someone knowledgeable in

the functional area it addresses, often at the Major Command level.

If a Major Command accepts the program responsibility, it becomes the sole manager/overseer of the program. An individual knowledgeable in both computer programming techniques and supply procedures is usually assigned the responsibility of fielding questions and solving problems discovered "in the field", as well as providing updates as they become necessary to all authorized users of the system.

A publication is produced on a recurring basis which is disseminated throughout the Air Force, identifying the many micro-computer based systems currently operational within the Air Force and providing information as to how an organization may be added to the distribution list to receive a desired computer program and its associated updates. This publication includes the name and functional address of the individual or organization responsible for the overall program management for each program, providing a vehicle for resolving program problems, receiving information regarding the program, etc.

Any tailoring required of a computer program to bring it in-line with specific Major Command procedures is generally completed by the program manager (at Major Command level). However, in the case of a program flowing between several Major Commands, this tailoring may be done in one of several ways: 1) By assigning a second program manager, this one serving within the Major Command who would like to make use

of the program; or 2) By individuals at the unit level who wish to make use of a specific program developed within another Major Command.

The simplest method of insuring cross-command applicability is to keep the program at a fairly generic, Air Force level, without incorporating information which is allowed to be changed by individual Major Commands. If this is not possible, the complexities of distributing the program across commands is increased dramatically (Turner, 1991).

The Standard Base Supply System (SBSS)

In order to identify a specific functional area within the SBSS in which to apply KBS technology, it is necessary to possess a fundamental understanding of the overall structure of this system. The following is an overview of the SBSS structure.

The SBSS represents a number of different individual organizations which together perform all supply-related duties at the base or wing level. The SBSS is lead by a Chief of Supply (COS), who is generally a senior officer with a great deal of experience within the 64XX (Supply Operations) career field.

The SBSS is broken down into five separate branches, each with a distinct role in the mission of the base-level supply account. These branches are: Management and Systems, Materiel Management, Materiel Storage and Distribution, Fuels Management, and Operations Support (AFM 67-1, 1987:3-53).

The Management and Systems branch provides support primarily to the Chief of Supply, and is comprised of the following sections: Customer Service and Training; Procedures and Analysis; Funds Management; Computer Operations; Inventory; Document Control; and Administration (AFM 67-1, 1987:2-53).

The Materiel Management Branch retains overall responsibility for all requirements identification, requisitioning, equipment, and inventory stockage issues within the SBSS. It is comprised of the following sections: Equipment Management; Stock Control; and Retail Sales (AFM 67-1, 1987:2-67).

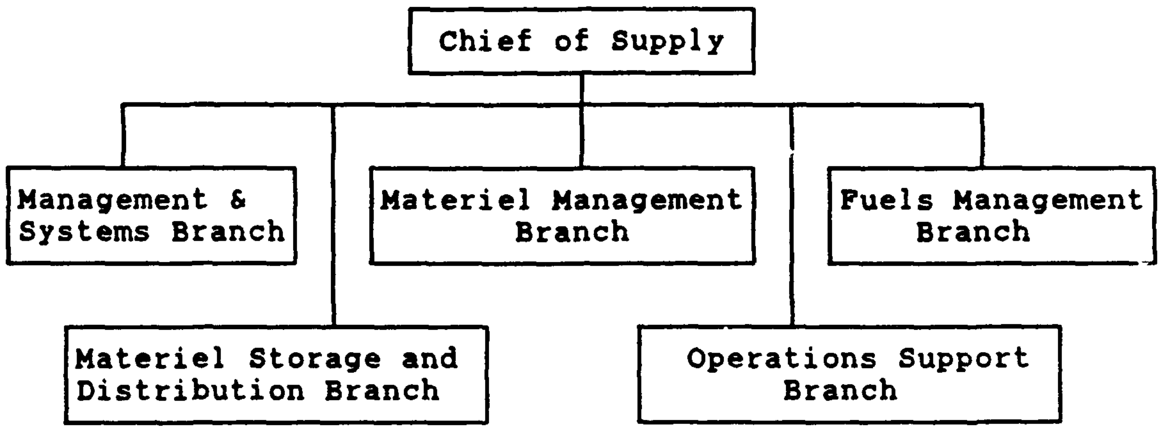
The Materiel Storage and Distribution branch maintains the responsibility for the efficient and effective handling and storage of all incoming and outgoing property. The branch is made of the following sections; Inspection; Receiving; Storage and Issue; Pickup and Delivery; and Bench Stock Support (AFM 67-1, 1987:2-83).

The Fuels Management Branch oversees the management of all petroleums, oils and lubricants (POL) used by wing or base organizations. It is made up of the following sections: Fuels Mobility and Training: Quality Control and Inspection; Fuels Operations; Cryogenics; and Accounting and Administration (AFM 67-1, 1987:2-87).

Finally, the Operations Support Branch is responsible for direct customer support, maintaining the following

sections: Demand Processing; Mission Support; and Repair Cycle Support (AFM 67-1, 1987:2-75).

Figure 8 illustrates the overall SBSS organization.



(AFM 67-1, 1987:Chap 2)

Figure 8. Overall Structure of the SBSS

Summary

Chapter II defined and outlined the short history of artificial intelligence and expert systems by tracing the literature on these topics. It also provided insight into the inner workings of expert systems/KBSs by examining literature regarding: 1) the structure of these systems; and 2) how to identify potential candidates for expert system implementation.

Chapter II further discussed the problems noted in past studies related to the maintenance and management of KBSs, focusing specifically on maintenance of systems within the USAF.

Shifting directions, Chapter II also provided an overview of the SBSS in an effort to impart a fundamental understanding of this complex system to the reader; this knowledge was critical during the problem selection phase of the research discussed in Chapter IV.

Chapter III will present an overview of the methodology used in this thesis to seek answers to the original research questions posed in Chapter I.

III. Methodology

Overview

Chapter III provides a discussion of the methodology selected for use in this thesis. It traces literature related to various methodologies which have been used in past research studies in developing and validating expert system/KBS projects.

Chapter III culminates with the presentation of a table which summarizes the specific methodology used in this thesis.

Introduction

While the technology of expert systems has been widely available for a relatively short time, numerous expert systems have been conceived, developed, tested, and implemented. As a base of experience developed in the best methods to conduct the process of creating an expert system/KBS, a pattern began to emerge. Essentially, all developmental aspects of a KBS can be observed to follow a set path. Different authors have given slightly different names to some of the developmental stages in expert system/KBS evolution; however, reviewing the literature reveals that the overall structure involved with creating an expert system remains consistent across virtually all applications.

Developing an Expert System/KBS

Before an expert system/KBS project can begin, a suitable problem must be discovered on which to apply the computer techniques. Thus, the first step in KBS development is identification of a good candidate problem. Methods for screening potential KBS applications have been developed by numerous researchers; these methods were discussed in Chapter II. Once the candidate KBS is selected, the development process may begin. Providing a comprehensive overview of the KBS development process, Allen (using information presented by Waterman) discusses the development process as presented in Table 3, below.

While Table 3 provides a good macro view of the KBS development process, a more complete step-by-step outline of the phases involved with developing an expert system/KBS are presented by Freiling et al..

According to Freiling et al., an expert system/KBS project may be broken down into two phases: the "knowledge definition phase" and the "prototype implementation phase" (Freiling et al., 1985:155-157).

Further, the knowledge definition phase can be broken down into three distinct steps, as follows:

Step 1: Familiarization. During this step, the person acting as the knowledge engineer attempts to determine the scope of the project and to understand the fundamental nature of the problem to be solved. Several data collection methods

Table 3

KBS DEVELOPMENT OVERVIEW

Method	Description
On-site observation	Watch the expert solving real problems on the job.
Problem discussion	Explore the kinds of data, knowledge, and procedures needed to solve specific problems.
Problem description	Have the expert describe a prototypical problem for each category of answer in the domain.
Problem analysis	Present the expert with a series of realistic problems to solve aloud, probing for the rationale behind the reasoning steps.
System refinement	Have the expert give you a series of problems to solve using the rules acquired from the interviews.
System examination	Have the expert examine and critique the prototype system's rules and control structure.
System validation	Present the cases solved by the expert and prototype system to other outside experts.

(Allen, 1986:79)

may be used during this step, including informal interviews with the expert selected, simple observation of the expert at work, and initial identification of other sources of domain information (e.g., regulations, manuals, etc.). This step is deemed complete when the knowledge engineer is able to combine all knowledge rules gained into an initial knowledge base (Freiling *et al.*, 1985:155-156).

Step 2: Organizing knowledge. This step picks up where step 1 left off, with the knowledge engineer examining the initial knowledge base created for patterns or regularities. The knowledge engineer then attempts to formulate the regularities found into the first of the heuristic decision rules, stated on paper in simple if-then form (Freiling et al., 1985:156-157).

Step 3: Representing knowledge. Once step 2 is complete, and all initial heuristic decision rules have been formulated on paper (and verified with the human expert), the knowledge engineer decides how the knowledge can be represented within the expert system. (Freiling et al., 1985:157).

Once steps one through three are complete, the second phase of the project, referred to as the Prototype Implementation Phase, can begin. According to Freiling et al.,

> Once the external and internal knowledge base formats have been defined, they can be used to guide the implementation of a prototype expert system. The implementation process consists of acquiring the knowledge base, building an inference engine, and building an appropriate interface. (Freiling et al., 1985:157-158)

Thus, the prototype implementation phase also involves three steps.

Step 1: Acquiring knowledge. During this step of prototype implementation, specific knowledge is collected and

processed into a data-base structure, which serves as the knowledge base for the expert system.

Step 2: Inference strategy design. In this step, the knowledge engineer choses a specific inference engine with which to drive the entire expert system, and completes the actual coding of the software which forms the core of the expert system.

Step 3: Interface design. Freiling et al. describe this step by saying, "Generally, this [step] involves trying to discover what parts of the task are routine and can be handled in an effective interface" (Freiling et al., 1985:158). Thus, in this final step, the system is tailored to meet the needs of the ultimate users.

Validation of the Expert System

Once the prototype expert system is developed, it should then go through a two-part validation/verification process to ensure it is functioning as intended.

The two processes, validation and verification, might seem to be one and the same process. However, in this instance, they are two distinct processes. O'Keefe et al. discusses the fundamental differences between the validation and verification processes as follows:

> Simply stated, validation refers to building the right system (that is, substantiating that a system performs with an acceptable level of accuracy), whereas verification refers to building the system "right" (that is, substantiating

> that a system correctly implements its specifications). (O'Keefe *et al.,* 1987:82)

Thus, the expert system/KBS being developed should be initially validated to ensure the program has been successfully "de-bugged" and thus returns reliable (internally consistent) answers to test problems. This validation can be conducted in several different ways, with perhaps the most common method being a rigorous test of the computer coding using problems where the answer is known in advance.

A second test of the system/KBS's usefulness comes in the form of the verification process, during which the question is asked "have we built the right model?" Oftentimes this question is very difficult to answer satisfactorily, due to the very nature of the problem under consideration. Allen notes that "The very nature of expert systems implies that there is no clear cut right or wrong answer to which the system addresses" (Allen, 1986:83). On this topic, Waterman notes:

> Evaluating an expert system is difficult because there may be no formal way to prove a given answer is correct or the best possible choice. The validity of the answer may depend on the persuasiveness of the argument given to support that answer. (Waterman, 1985:198)

However, despite this ambiguity in determining the usefulness of a computer model via the verification process, an attempt must be made to demonstrate that the right system has been built to solve a particular problem.

Waterman presents an answer to this dilemma in his discussion of one method for completing the verification process; Waterman states:

> The knowledge engineer presents the... prototype system to other experts. This provides a way to compare strategies of different experts and find essential points of disagreement. (Waterman, 1985:160-161)

Summary of Methodology Used in the Thesis

Compiling all relevant methodological considerations presented in the literature, Table 4 presents an overview of the specific methodology which was used to answer the research questions posed in Chapter I.

Summary

Chapter III provided a comprehensive overview of the steps taken in this thesis to discover answers to the research questions posed in Chapter I. It briefly traced past methodologies which have been used in KBS development, and concluded with a summary of the specific methodology used in this research.

The information presented in Chapter III sets the stage for the more-specific discussion which takes place in Chapter IV. Chapter IV discusses the implementation of the methodology established in Chapter III, and provides findings to the research questions posed in Chapter I.

Table 4

OVERVIEW OF SPECIFIC METHODOLOGY USED

Research Process	Specific Methodology
Step 1: KBS Candidate Selection	- Research historical problem areas within Base Supply. - Select the one best candidate for KBS development. - Discuss expert system/KBS implementation with an expert in the problem area identified, to insure need/feasibility.
Step 2: Problem Familiarization	- Discuss problem with the expert. - Collect all knowledge available on the problem (from the expert, manuals, regulations, etc.).
Step 3: Prototype Development	- Select expert system shell to be used in program. - Create the initial knowledge base from information gathered in step 2. - De-bug program - eliminate syntactical problems.
Step 4: Validation and Verification	- Present completed prototype to other experts to validate assumptions/usefulness of the program. - Test the program on novices in the field

IV. Findings and Discussion

Overview

Chapter IV provides an overview of the specific actions taken by the researcher in answering the original research questions posed in Chapter I. As developed in Chapter III, a four-step methodology was employed, briefly summarized as:

Step 1: KBS Candidate Selection

Step 2: Problem Familiarization

Step 3: Prototype Development

Step 4: Validation and Verification

These processes, which eventually led to the creation and validation of the prototype KBS named the "Equipment Management System Management Advisory Program" (EMS MAP), are presented below.

Step 1: KBS Candidate Selection

The first issue dealt with the selection of an existing supply-related problem in which to apply a KBS.

An answer to this problem came in the form of a draft report prepared by the Air Force Logistics Management Support System (LIMSS) for the Air Force Logistics and Engineering Information Systems Division. This report provided a summary of a survey undertaken to identify existing KBS applications and to discuss "the feasibility and benefits of specific candidate logistics (KBS) applications" (U.S. DOT, 1990:iii).

Specifically, the report issued by the LIMSS was initiated:

> in an effort to identify AI applications with a significant payback... A number of candidate applications have been identified through interviews with potential users, government organizations responsible for developing [KBS] applications and representatives of the LIMSS program. (U.S. DOT, 1990:iii).

The report investigated potentially lucrative KBS applications within the following distinct functional areas: Supply; Munitions; Maintenance; Transportation; Engineering and Services; and Command and Control.

In the Supply functional area, four high-priority KBS candidates were identified, selected for their high potential for improved efficiency via manpower savings. Of these four recommended KBS applications, the one which appeared to offer the most appropriate problem (in terms of degree of difficulty and familiarity of the author to the general topic considered) was one proposed by Lt Col Peterson from the Air Force Logistics Management Center (office symbol AFLMC/LGK).

Lt Col Peterson's proposal was directed at improving the ability of base-level equipment custodians in completing their day-to-day custodian duties. These duties generally involve interfacing with the Equipment Management Section (EMS) within the base-level supply account in ordering, maintaining, and overseeing their organization's equipment account.

In his proposal, Lt Col Peterson states:

> The Logistics Management Center has identified a need for a system to assist in ordering items of equipment. There are a large number of regulations governing how to place an order, and mistakes are often made [by equipment custodians] in preparing the required forms. This results in delays as incorrect order forms are returned for resubmission. The situation is further affected by the high turnover of staff.

Further investigation into the problem described by Lt Col Peterson tangentially led to a report prepared by Captain Jeff Bailey from the Air Force Logistics Management Center (AFLMC) in November 1989 titled "Analysis of Base-Level Supply Customer Training". Lt Col Peterson served as a team member in the preparation of this report.

Captain Bailey's report was the result of a HQ USAF/LEY tasking to the AFLMC to review the Air Force supply customer training program. Captain Bailey's stated objective for the study was "to analyze the supply customer training program, determine customer training needs, and recommend improvements to the program to meet those needs" (Bailey, 1989:i). In his report, Captain Bailey notes that "a common perception among supply customers and trainers is that supply customer training is inconsistent from one base to another" (Bailey, 1989:1).

This inconsistency in training was resulting in inconsistent application by supply users (e.g., equipment custodians) in the performance of supply duties. In a broad

sense, the knowledge required of supply customers (including equipment custodians) includes:

1) a basic understanding of computer-generated listings received from base-level supply;

2) an ability to correctly fill out required supply paperwork;

3) an ability to keep their supply records in order;

4) a knowledge of who they may contact within the base-level supply account to answer their questions (Bailey, 1989:1).

Captain Bailey determined (and listed in Appendix D to his report) what he considered to be the most important topics to be covered during the initial equipment custodian training session. These topics were:

1. Equipment Management Section (EMS) points of contact.

2. The Air Force Equipment Management System (AFEMS).

3. Equipment responsibilities.

4. Allowances and authorizations.

5. How to read a Table of Allowances (TA).

6. Equipment turn-in procedures.

7. How to fill out an AF Form 2005.

8. How to fill out an AF Form 601.

9. Custodian Authorization/Custody Receipt Listing (CA/CRL).

10. How to establish and maintain an equipment custodian file (Bailey, 1989:15).

According to Captain Bailey, many of the individual supply customers who were surveyed as a part of his study felt that the best way to provide the required training and information was through the use of a short classroom lecture combined with a source of information (such as a hand-out) which the customer could take back to his or her workplace which would act as a guide for future supply actions.

From the above information, it appeared likely that a computerized product in the form of a KBS which would contain a compilation of information (both from an expert and from manual/regulation guidance) could improve the ability of equipment custodians to complete their day-to-day supply tasks. To verify the applicability of this type of a project, and to determine the feasibility of producing such a product, an individual knowledgeable in the training of equipment custodians was consulted.

Ms. Jody Taylor (GS-11), the head of the Wright-Patterson AFB Base Supply Training Section, indicated that the premier expert on training issues regarding equipment management was SSgt Jackson, who also worked in the Training Section. SSgt Jackson was contacted and an initial interview was held, yielding the following information:

1) Approximately 900 equipment accounts were currently operational at Wright-Patterson AFB.

2) SSgt Jackson was responsible for conducting all training sessions for newly assigned equipment custodians.

SSgt Jackson possessed a great deal of experience in equipment matters, and was generally regarded as the expert in this area by equipment custodians at Wright-Patterson AFB.

3) SSgt Jackson had developed a handbook to be given to newly trained equipment custodians to serve as a basic guide for future equipment actions. However, SSgt Jackson reported that the use of the handout was limited, and that he routinely received phone calls from equipment custodians asking for further assistance on specific equipment matters.

4) The information which would serve as the knowledge base for this program was readily available in several different Air Force Regulations and Manuals. Also, SSgt Jackson was willing to serve as the expert in this project.

From the above information, it was determined that the KBS project under consideration was both feasible and desirable. Thus, this project was determined to be the one which would be used in conducting the research study.

<u>Step 2: Problem Familiarization</u>

The problem familiarization step took place over the course of approximately three months, and involved gathering information from several sources.

The first source of information was SSgt Jackson, the individual deemed to be the expert in equipment management matters at Wright-Patterson AFB. Through interviews with SSgt Jackson, the "big picture" of the equipment management function gradually emerged, and a foundation of understanding

regarding the tasks required of an equipment custodian was developed.

SSgt Jackson also provided the researcher with all pertinent references for equipment information to be found in Air Force Regulations and Manuals, and also provided the researcher with a copy of the locally developed equipment handbook given to newly trained equipment custodians. These additional sources were consulted over the entire knowledge familiarization phase, and provided useful information to be incorporated into the prototype KBS.

Captain Bailey's research project was discussed with SSgt Jackson, who concurred that the 10 items identified by Captain Bailey as vital training topics. Further, SSgt Jackson recommended that the equipment custodian KBS to be developed should attempt to follow these general topics in presenting its information.

Step 3: Prototype Development

The actual prototype development step commenced once the application to be completed was determined and all knowledge available on this topic was gathered.

To begin this step, a determination was required as to which of the several commercially available expert system shells would be used to actually code the program. The PC-based expert system shell "VP-Expert" was chosen, primarily due to its ease of operation and the researcher's familiarization with this shell. Additionally, built-in

features providing for such things as windows, colors, and mathematical operations made "VP-Expert" a good choice for this project.

Next, the actual coding of the knowledge base began. It was decided to create an overall structure which was in-line with that proposed by Captain Bailey for completing the equipment custodian training session. Thus, major topics available from the main menu were:

1. "Welcome New Users." This portion of the EMS MAP provided basic program information to new users, including the purpose of the program and fundamental concepts related to its use.

2. "AFEMS Overview." This module provided basic information regarding the Air Force Equipment Management System (AFEMS).

3. "Points of Contact." This module gave the user the names and duty phone numbers of key personnel within Base Supply, including individuals within the Equipment Management Section and the Customer Service Section.

4. "Definitions." This portion enabled the user to select from a menu of equipment-related terms, providing a short definition of the term to assist the equipment custodian.

5. "Acronyms." Similar to the "Definitions" module, this portion provided a menu of supply acronyms for the user to select from; upon selection, the program displayed a brief explanation of the acronym selected.

6. "Responsibilities." This module provided the user with an overview of the responsibilities of the equipment custodian, the organizational commander, the responsibility center manager, and the cost center manager.

7. "Folder Maintenance." This portion of the EMS MAP provided a step-by-step set of procedures for maintaining the required equipment custodian folder.

8. "CA/CRL Overview." This module provided the user with an overview of the Custodian Authorization/Custodial Receipt Listing (CA/CRL). This listing is used extensively by equipment custodians; an understanding of its use is essential in maintaining an equipment account.

9. "Help with Forms." This portion of the program provided the user ˙˵h basic information on the various forms required of an equipment custodian. It also provided advice to the custodian on which form he/she should use, after asking the user several questions to determine the appropriate form.

This menu system provided the overall structure for the prototype KBS; each menu item served as a separate module for the knowledge engineer (the researcher, in this case) to code into the program.

The vast majority of the information coded into the KBS's knowledge base came directly from written materials; Air Force Manual 67-1, Air Force Regulation 67-23, and SSgt Jackson's locally developed equipment handbook were each used

extensively in this phase of program development. The expert knowledge of SSgt Jackson was used primarily as an overall "control structure". This knowledge provided coherence and flow to the program from a human point of view, ensuring the information was being presented in a useful, easily accessible fashion, from an equipment manager's standpoint.

The focus during this step of the prototype development was on creating a KBS which would provide fast and user-friendly access to the plethora of equipment guidance found in several different official sources. Attempts were made to incorporate expert advice (coming from SSgt Jackson) to supplement the regulatory guidance provided, thus providing a source of information more like that found when consulting with an actual expert in the equipment management field.

As each new module completed the initial coding phase, SSgt Jackson was consulted to ensure that the module in question was providing correct answers to basic user queries. Syntactical errors identified by "VP-Expert" were dealt with as they occurred.

The KBS exhibited ever-increasing capabilities as new modules were programed; the module programming phase, when finished, led to the determination that the initial prototype KBS was complete. This "first-draft" KBS was then given the name of "The Equipment Management System Management Advisory Program" (or EMS MAP), and was presented to SSgt Jackson for initial testing and validation.

Step 4: Validation and Verification

Type of Validation/Verification. In order to validate and verify the KBS created, the researcher selected a multi-level process. For maximum effectiveness, a single equipment expert at the base, MAJCOM, and HQ USAF level was selected (based on the recommendations of CMSgt Conley, HQ USAF/LEYS, and the researcher's base-level equipment experience). This was done for three reasons:

1. To ensure that the prototype KBS achieved its intended cross-command applicability.

2. To enhance the liklihood for successful implementation of the candidate KBS through the use of experts at three different management levels.

3. To provide additional credibility to the validation/ verification process.

Selection of Validating Experts. The credentials of the experts selected and the rationale behind their selection (beginning at the HQ USAF level) are as follows.

To act as the USAF-level validating expert, CMSgt Babbitt was selected. Currently serving at HQ USAF/LGSS, CMSgt Babbitt combines years of supply experience with a relatively powerful position within the overall USAF Supply community. Serving in a position designed to oversee the entire Air Force Supply System, CMSgt Babbitt's opinion on virtually any supply matter carries considerable weight.

SMSgt Abeln, serving at HQ SAC/LGSEP, was selected as the MAJCOM-level validation expert. His selection was based on several factors:

1. HQ SAC was selected as the MAJCOM to be used for the validation process, due to the researcher's experience within this command.

2. Key managers within the HQ SAC Supply Directorate were contacted by the researcher and were asked to recommend the premier equipment expert within the command's headquarters. SMSgt Abeln was the overwhelming choice, based on his extensive supply experience within SAC and his current participation in the automated Air Force Equipment Management System (AFEMS) project.

3. SMSgt Abeln was then contacted and asked to participate in the validation of the EMS MAP; his willingness to participate in the project finalized his selection as the MAJCOM-level validation expert.

Finally, CMSgt Robert Fatula, serving within the 384th Supply Squadron at McConnell Air Force Base (SAC), was selected as the base-level validation expert. The researcher selected this individual based on first-hand knowledge of the equipment experience possessed by CMSgt Fatula, coupled with the individual's willingness to participate as the equipment validation expert.

<u>The Validation/Verification Process.</u> Once the experts to be used in the validation/verification process were

selected and initially contacted, the process was set to begin. A letter was drafted and forwarded to each of the three experts along with a copy of the prototype KBS. This letter (presented in Appendix B) briefly described the intended purpose of the "EMS MAP" program, gave instructions for its use, and requested that the experts test the program as they saw fit. Once the experts had completed their testing of the program, they were asked to form an opinion of the validity of the program based on the following general guidelines:

1. What is your overall impression of the program?
2. Remembering that the program was written for use by novice equipment custodians, do you think the program (as it stands) would be useful?
3. What items appearing in the program are incorrect or inappropriate? (in other words, what would you change about it to make it better).
4. Finally, what items would you like to see added to the program to make it more useful to an inexperienced equipment custodian?

Telephone interviews were conducted to receive feedback from the equipment validators at the base and HQ USAF levels. The researcher was afforded the opportunity to meet face-to-face with SMSgt Abeln, the HQ SAC equipment expert acting as the MAJCOM-level validator. The specific recommendations made by SMSgt Abeln during the KBS validation visit, as well

as the recommendations made by the other two equipment validators, are presented in Appendix C.

After receiving feedback from each of the equipment validators, the "EMS MAP" was updated to incorporate the recommendations given by the experts. After these changes had been made, a session was conducted with SSgt Jackson (the original expert used to create the program) to ensure the changes had not altered the basic intent of the program from this individual's standpoint.

As a final step in the validation/verification process, the completed KBS prototype was tested using a non-random selection of newly trained equipment custodians. This step was intended to determine whether or not the completed program, developed by equipment experts, would be useable by individuals less-knowledgeable in equipment procedures.

To begin this step, volunteers were solicited from a group of individuals attending the initial equipment custodian training within the Training Section of Wright-Patterson's Base Supply account. Five individuals agreed to assist in the validation of the KBS, which took place immediately after the training session was completed. Having received the only formal equipment training available, these individuals appeared to fairly represent the category of novice equipment custodians.

Each of the novice equipment custodians who volunteered was afforded the opportunity to work with the prototype KBS

for approximately 15 minutes. This amount of time was sufficient for the volunteers to observe the overall control structure of the program, and to receive advice from the KBS on a number of issues pertinent to an equipment custodian's daily tasks. Through interface with the novice equipment custodians and SSgt Jackson (the original equipment expert), the researcher was able to determine that the prototype KBS provided adequate user-friendliness for newly trained equipment custodians. Further, based on the replies from the volunteers, the information presented by the program appeared to be very useful in performing an equipment custodian's everyday tasks. Thus, no changes to the program were required as a result of this final validation/verification step.

With the completion of the validation/verification step of prototype development, the first-generation "EMS MAP" prototype KBS was deemed complete.

Summary

Chapter IV presented a more-specific overview of the steps taken to answer the research questions posed in Chapter I. These steps were comprised of:

Step 1: KBS Candidate Selection

Step 2: Problem Familiarization

Step 3: Prototype Development

Step 4: Validation and Verification

Specific actions taken during each of these four steps was outlined in Chapter IV. The results of these methodological steps, culminating with the initial prototype completion of the "Equipment Management System Management Advisory Program," were presented in Chapter IV.

Chapter V will discuss the overall conclusions of this study, specifically dealing with how this research process has answered the three research question posed in Chapter I. Finally, recommendations which have resulted from the research conducted in this thesis will be presented.

V. Conclusions and Recommendations

Overview

Chapter V begins with a presentation of the overall conclusions of the research, relating these conclusions back to the original research questions posed in Chapter I. Additional conclusions made by the researcher are also presented. Chapter V also presents three recommendations for further studies related to the field of artificial intelligence.

Conclusions of the Research

In terms of the three research questions posed in Chapter I, the research conducted in this thesis (as summarized in Chapters I through IV) has yielded the following conclusions:

Research Question 1. Do supply-related tasks lend themselves to KBS development? As introduced in Chapter I and further developed in Chapter II, the Standard Base Supply System represents an organization which could indeed benefit from the introduction of KBS technology.

Specifically, it was found that organizations characterized by a relative shortage of experts and a rigid, manual-driven set of procedures were prime candidates for KBS development. Through discussion in Chapters I and II, the SBSS was shown as just such an organization. Within the Standard Base Supply System, the training of equipment

custodians was identified as one specific task which could benefit from the introduction of KBS technology.

Thus, in answer to the first research question, supply-related tasks do lend themselves to KBS development.

Research Question 2. If supply-related tasks lend themselves to KBSs, how can a prototype KBS be developed within the Standard Base Supply System? As illustrated by Chapter IV, the prototype KBS titled the "Equipment Management System Management Advisory Program (EMS MAP)" was created by the researcher. Using an expert from Wright-Patterson Air Force Base's Base Supply Training Section and various manuals and regulations, the EMS MAP provides answers to questions commonly posed by equipment custodians in their day-to-day account management.

Thus, Research Question 2 was also confirmed with the development of the KBS titled EMS MAP.

Research Question 3. How can this prototype KBS be validated? As presented in Chapter IV, the prototype KBS developed in this research was put through a multi-level verification/validation process. Using independent equipment experts at the HQ USAF, HQ SAC, and base levels, the validity of the prototype KBS was confirmed, culminating in the initial completion and acceptance of the EMS MAP within Wright-Patterson's Base Supply Training Section.

Thus, Research Question 3 was also answered affirmatively.

Additional Conclusions. With the resolution of the three research questions posed in Chapter I, this thesis was nearly complete. However, two additional conclusions were drawn by the researcher.

First, in the course of conducting research into the topic of artificial intelligence, expert systems, and knowledge-based systems, the researcher found that these mysterious-sounding computer sub-fields possess a great deal of pragmatic and relatively straightforward value in everyday computer applications. However, the concept of applying artificial intelligence techniques within the Standard Base Supply System was considered a truly revolutionary concept to many supply experts consulted by the researcher. At the same time, however, these same experts were actively involved in implementing numerous small-scale PC applications involving data-base management techniques.

Thus, it appears that the "demystification" of the practical uses of expert system technology within our logistics areas has not been completely successful yet. Unless the mystery of this fertile subfield of computer technology is removed from the minds of potential users, numerous candidate processes for KBS application will continue to be completed in a less-efficient, manual manner.

With the downsizing of our military forces in post-Operation Desert Storm America, every effort must be made to capture the dwindling expertise still possessed and to press forward with all potentially lucrative sources of increased

efficiency. One way to do this is through the expanded use of expert and knowledge-based system technology.

A second conclusion was drawn by the researcher regarding the actual prototype KBS development process. It was determined that the application of expert system technology within the logistics doctrines need not involve great expense in either actual dollars or manpower.

The KBS developed in this thesis, while somewhat limited in scope, demonstrates the enormous potential for KBS technology in automating many small-scale problems. While extremely large-scale expert systems exist which have required a great deal of time and money to develop, it was found that many small-scale problems existed within the logistics functions which could be solved via a small-scale expert system. Thus, a continued focus should be placed on expert system education in an effort to provide a catalyst for the development of additional small-scale expert systems.

Recommended Follow-On Studies

In completing this thesis, several additional avenues of potentially useful research became evident to the researcher. These additional research projects include:

Expert System Roadmaps. While it was relatively easy to select a candidate problem for KBS implementation, it appears useful for research to be conducted to develop some sort of roadmap for future expansion of expert and knowledge-based technology within each of the logistics areas (Supply,

Transportation, Maintenance, and Logistics Plans). Hinted at by Colonel Blazer in his AFIT Form 53 ("External Proposal - Thesis Research Topic," see Appendix A), a need exists to "identify potential expert systems for each of the logistics functional areas" (Blazer, 1990). This research could include the development and testing of a standardized methodology for prioritizing potential logistics KBS applications into a top-down list of good candidates.

Determining the Level of Understanding of Expert System Concepts Within the Logistics Areas. Research in this area might involve a survey of individuals working within each of the logistics disciplines to determine the level of knowledge and/or fear of artificial intelligence techniques. In line with comments made in the "Additional Conclusions" section of this chapter, it is felt by the researcher that ignorance prevails within many logistics organizations as to the practical value and relative simplicity of many knowledge-based computer programs. The true state of knowledge regarding expert systems technology would be assessed in this recommended research. If knowledge of expert systems applications was found to be lacking within logistics organizations, methods to increase the knowledge level or reduce the fear level might be explored in this follow-on research.

Additional Prototype Expert Systems. The logistics area (and, in particular, the Standard Base Supply System) was

found to be an area possessing numerous processes which could be made more efficient via expert or knowledge-based system application. The research conducted here demonstrated the feasibility of small-scale prototype development of KBSs using only limited means. Thus, it is imperative that additional KBS applications be completed within the logistics arena to continue to streamline our logistics processes and stem the loss of expert knowledge.

Also, as noted in the "Additional Conclusions" section of this chapter, expert or knowledge-based systems can be developed to solve small-scale logistics problems with very limited dollar and manpower requirements. Chapters III and IV of this thesis provide a sound methodology for developing and validating a small-scale KBS. Thus, additional research is needed to develop and validate small-scale expert systems within each of the logistics functions.

Summary

Chapter V began by presenting the conclusions of the research, including an answer to each of the Chapter I Research Questions. Two additional conclusions which resulted from the research process were also discussed.

Chapter V concluded with three recommendations for follow-on studies related to the field of artificial intelligence within the U.S. military logistics structure.

Appendix A: AFIT Form 53

EXTERNAL PROPOSAL - THESIS RESEARCH TOPIC

School of Systems and Logistics
Air Force Institute of Technology (AU)
Wright-Patterson AFB OH 45433

FOR LSB USE ONLY

INTERESTED FACULTY

90-95

1. TOPIC AREA: Artificial Intelligence

2. NAME: Col D. Blazer

3. COMMAND/BASE: Pentagon
HQ USAF/LEXX

4. ORGANIZATION: Air Staff

5. OFFICE PHONE/EXT: AV225-6712

6. IN ONE SENTENCE, HOW WOULD YOU STATE THE PROBLEM?

Expert Systems in Logistics Processes

a. Identify potential expert systems for each of the logistics functional areas.

b. And/or Build a prototype expert system for a particular logistics process application.

7. PLEASE INDICATE THE BASIC FACTOR, RELATIONSHIPS, AND SITUATIONS INVOLVED. (Use a sheet of bond paper, if necessary.)

Expert Systems are computer programs that guide a novice through a series of decisions so the novice can make expert decisions. There are an endless number of potential applications for expert systems in all the logistics functional area processes. Research in this area could include a review of a logistics function (supply, transportation, maintenance, engineering, logplans, or contracting) to identify potential expert system applications. The report would provide a roadmap for development of expert systems. Other research efforts would include the development of expert systems for specific applications (for example the contractor buying or the supply stock fund manager).

8. PLEASE INDICATE INDIVIDUALS, STUDIES, OR OTHER PUBLICATIONS THAT CAN FURNISH RESOURCES FOR THIS RESEARCH.

Depends on the functional area selected, but other sources include: AFLC HQ/XP and MMI, AFLMC, HQ USAF/LEYS

9. PLEASE INDICATE THE LOCATION OF EXISTING AVAILABLE DATA SOURCES AND THE FORM OF THE DATA.

Depends on function selected, however, HQ AFLC/MMI or WP AFB Base Supply

AFIT Form 53, AUG 86 (LSB) PREVIOUS EDITION IS OBSOLETE

Appendix B: Sample Expert Validator Letter

From: Capt Rick Nelson 13 Jul 91

Subject: Computer Program Validation

To: Equipment Expert Validators

1. Here's the computer program we talked about today. As I mentioned, this program is a part of my Master's Thesis here at AFIT, and your help in evaluating/validating/improving it will help me out quite a bit. The program itself should be fairly self-explanatory. To run the program, all you need to do is to insert the diskette into your computer's A drive, type in "Run" and press Return.

2. How you can help me is by going through the program for a while, looking at its capabilities and the actual information I've coded into the program to make sure everything makes sense from an equipment standpoint. If you see things in the program which are incorrect (or just simply inappropriate, in your opinion), make a note of the specific item in order to answer the questions, below.

3. When you get done checking out the program to your satisfaction, please be prepared to discuss the program with me using the following questions for guidelines:

   a. What is your overall impression of the program?

   b. Remembering that the program was written for use by novice equipment custodians, do you think the program (as it stands) would be useful?

   c. What items appearing in the program are incorrect or inappropriate? (in other words, what would you change about it to make it better).

   d. Finally, what items would you like to see added to the program to make it more useful to an inexperienced equipment custodian?

4. If you have any questions, you can get a message through to me by calling AV 785-8989.

RICHARD G. NELSON, Capt, USAF

Atch:
EMS MAP Program

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Vita

Captain Richard G. Nelson was born on 10 July 1963 in Omaha, Nebraska. He graduated from Central High School in Omaha, Nebraska in 1981 and subsequently attended the University of Nebraska at Omaha, where he graduated in December of 1985 with a Bachelor of Science in Business Administration, majoring in Business Finance. He was commissioned as a Second Lieutenent in the United States Air Force from Officer Training School in May 1987.

Captain Nelson's first assignment was to McConnell Air Force Base in Wichita, Kansas. Assigned to the 384th Supply Squadron initially as the Officer in Charge of the Bomber/Tanker Support Section, he oversaw the establishment of initial flightline supply support for the newly assigned fleet of B1-Bombers.

Captain Nelson next attended the Supply Operations Officer Course at Lowry Air Force Base, Colorado, from January through March of 1988, earning Distinguished Graduate honors. Upon his return to the 384th Supply Squadron in March, 1988, Captain Nelson was placed in charge of the Materiel Management Branch, where he oversaw the Stock Control, Equipment Management, and Retail Sales Sections until entering the School of Systems and Logistics, Air Force Institute of Technology, in May of 1990.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

AN APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY WITHIN THE STANDARD BASE SUPPLY SYSTEM

5. FUNDING NUMBERS

6. AUTHOR(S)

Richard G. Nelson, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Institute of Technology
Wright-Patterson AFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GLM/LSM/91S-49

9. SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a DISTRIBUTION AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This thesis investigated the feasibility of applying artificial intelligence technology within the Standard Base Supply System (SBSS). With seemingly endless reductions in manpower authorizations within the SBSS and the potential for a continued loss of expert knowledge, the use of knowledge-based systems (KBSs) was examined to determine if these systems could alleviate this loss of manpower. Literature related to the fields of artificial intelligence, expert systems, and KBSs was traced, yielding a methodology for identification of candidate problems, and for the development, verification, and validation of a prototype KBS. The research resulted in several conclusions: 1) Supply-related tasks do lend themselves to KBS development: 2) A small-scale Supply KBS is feasible with limited resources; and 3) A small-scale Supply KBS can be validated. Several follow-on studies were recommended, with the thrust being that additional KBSs should be developed, tested, and placed into operational use within the SBSS.

14. SUBJECT TERMS

Artificial Intelligence, Expert Systems, Computer Programs, Knowledge-Based Systems

15. NUMBER OF PAGES

79

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

AFIT Control Number AFIT/GLM/LSM/91S-49

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